

THE WEATHER AND CIRCULATION OF MARCH 1955¹

A Month of Extreme Heat and Cold Over the United States

JAY S. WINSTON

Extended Forecast Section, U. S. Weather Bureau, Washington, D. C.

1. MARKED TEMPERATURE VARIATIONS

The pattern of average temperature anomaly in the United States for March 1955 was essentially simple—cold weather in the North and West and warm weather over the South and East (Chart I-B). However, in many sections of the country temperatures varied in such an extreme manner during March that mean temperature anomalies for the month as a whole do not provide sufficient information about the basic character of the tem-

perature regime. The broad-scale variations in temperature during the month are more clearly revealed by a set of weekly temperature anomaly charts covering most of March (fig. 1).

Figure 1A illustrates the great contrasts in temperature that existed between various parts of the country during the first week of the month. Temperatures over the Northern Plains and the Far West were close to normal values for *January* while those in the East and South were like the normals for *May*. During the second week of the month (fig. 1B) warm weather became dominant over

¹See Charts I-XV following p. 82 for analyzed climatological data for the month.

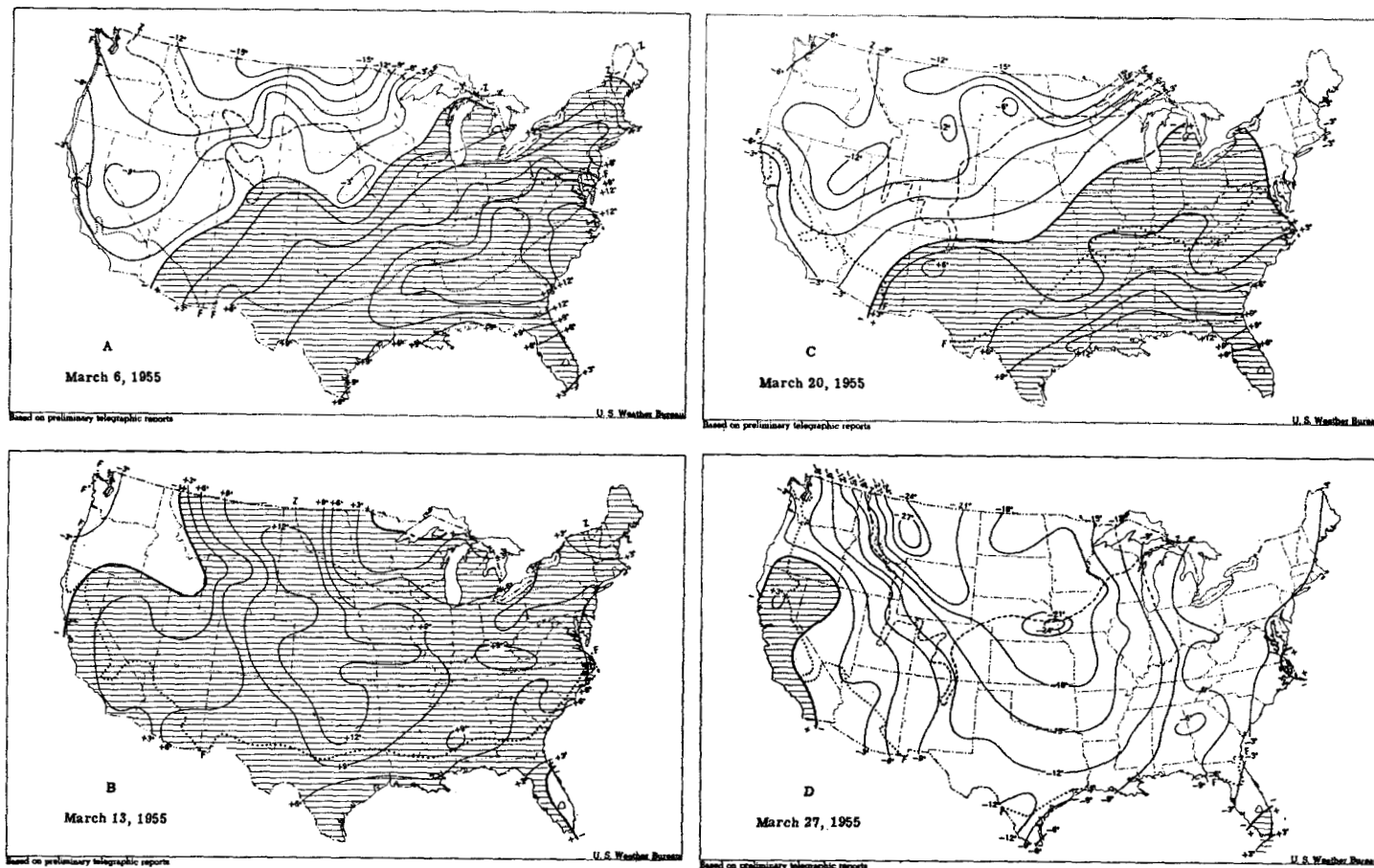


FIGURE 1.—Departure of average temperature from normal (°F.) for the weeks ending at midnight, local time, on the dates shown. Shading indicates temperatures of normal or above; dotted line shows southern limit of freezing temperatures; dashed line, southern limit of outbreak of extremely cold air in the week ending March 27.

almost the entire country. The biggest change from the first week was in the Northern Plains and the Southwest, where temperatures were almost as far above normal as they had been below normal the week before. But this rapid emergence of spring in these areas was quickly terminated by new invasions of cold air in the third week (fig. 1C). Some cooling also set in over middle and northeastern sections of the country by the third week, but temperatures remained well above normal in the South. The fourth week was essentially the climax of the month, temperature-wise, as extremely frigid air swept through virtually the entire country (fig. 1D). Temperatures characteristic of midwinter prevailed almost everywhere, and record-low temperatures for this late in the season were observed at most stations in the South and Midwest. Some statistics of this cold wave are given in table 1 of the adjoining article by Kibler and Martin [1].

The fact that the cold wave followed almost directly on the heels of a major March heat wave added to its remarkable and damaging nature. For, during the second and third weeks of March new records for early-season warmth were set at many locations in the middle and eastern sections of the country. This prevailing warmth caused early blooming of fruit trees and other crops in middle, southern, and southeastern portions of the country. Thus plants and trees in these areas were especially vulnerable to the severe frost that accompanied the cold wave even as far south as the Gulf Coast. Preliminary estimates of crop loss due to the cold wave ran as high as \$50 million.

2. CONTROLLING CIRCULATION FEATURES

The struggle for dominance between warm and cold air over the United States in March was governed by some fundamental changes in the planetary wave pattern as the month progressed. Fifteen-day mean charts for the two halves of March conveniently portray these events (fig. 2).

During the first half of March (fig. 2A) the circulation pattern at middle and higher latitudes from the Asiatic coast eastward to the central Atlantic consisted of waves of rather large longitudinal dimensions. The key features of this pattern—a trough along the Asiatic coast, a ridge over the eastern Pacific, and a trough over Canada—were all displaced well to the west of the positions of corresponding troughs and ridges found on the normal 700-mb. chart for March [2]. The ridge was located farthest from its normal counterpart—some 20° to 25° of longitude west of the normal ridge over western Canada. Its position over the Gulf of Alaska was very unusual since this area has been found (according to studies now going on in the Extended Forecast Section) to be a zone of minimum frequency of occurrence of both 5-day and 30-day mean ridges at this season in recent years. This ridge, incidentally, was in virtually the same position as during the second half of February [3], when a strong northwesterly

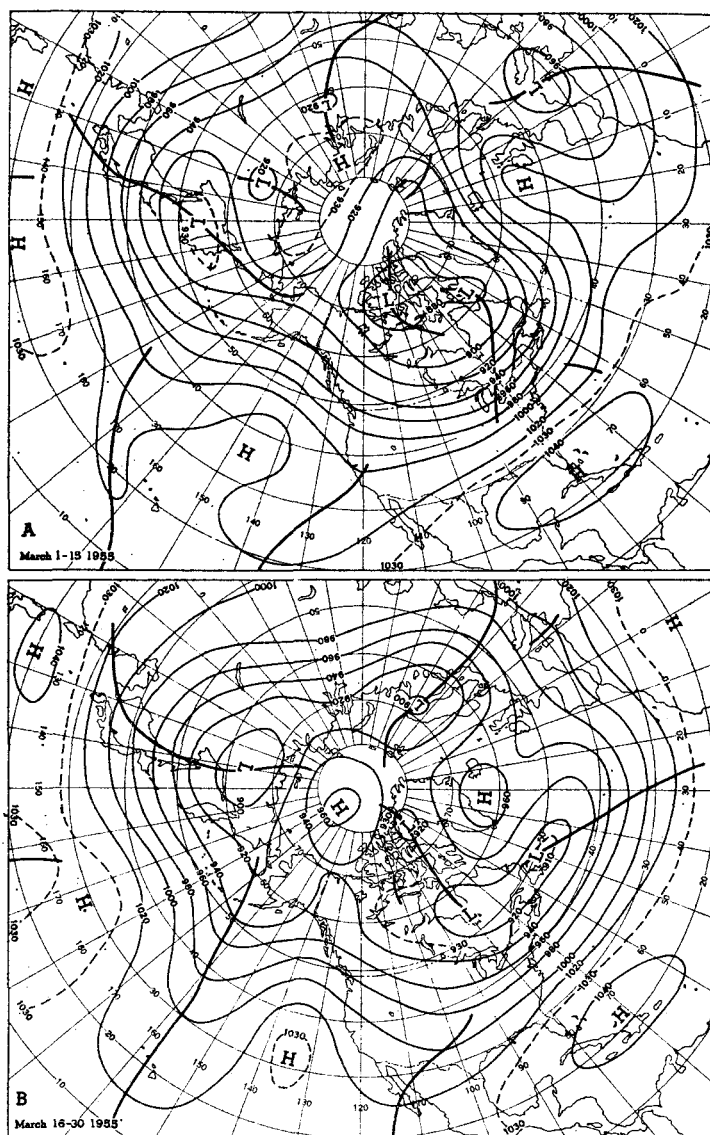


FIGURE 2.—Mean 700-mb. contours (tens of feet) for (A) March 1-15 and (B) March 16-30, 1955. Confluence over west-central United States in first half of March was weakened and shifted to southeastern United States by second half as new wave in Pacific caused eastward motion of middle and lower latitude wave train, while blocking action over Atlantic and Canada depressed westerlies southward.

flow of cold air became established over western North America. Although the ridge decreased in amplitude somewhat during the first half of March, anomalous northwesterly flow persisted over western Canada and Northwestern United States.

Over the west-central United States this cold northwesterly current flowed alongside a warm southwesterly current emanating from relatively low latitudes. This confluence zone was associated with the out-of-phase nature of the wave patterns at higher and lower latitudes. For, a low-latitude trough was situated south-southeast of the eastern Pacific ridge, while a subtropical anticyclone over the southeastern United States and the West Indies was

directly south of the Canadian trough. This confluence over the west-central United States essentially confined the cold air to northwestern and western sections of the country and to areas north of the Canadian border. Meanwhile warm air prevailed south of the confluence zone in the South and under the fast zonal flow downstream from the confluence zone in the East (figs. 1A, B). Confluence persisted sufficiently during part of the third week of March to keep the surface temperature pattern for that period basically similar (fig. 1C).

However, substantial changes in the flow pattern were occurring around mid-March to bring an end to confluence over the western United States. The numerical changes in 700-mb. height between the first and second halves of March are shown in figure 3 and the resulting flow pattern is portrayed in figure 2B. The greatest changes in circulation occurred over the Atlantic, Greenland, and Canada as blocking action occurred. A closed anticyclone developed between Greenland and Iceland, while a deep trough became established to its south, extending from Newfoundland southeastward toward the eastern subtropical Atlantic. This blocking anticyclone stemmed from the High which was west of Great Britain in the first half of March (fig. 2A). Effects of this blocking activity extended well westward as indicated by the sizeable height rises through virtually all of Canada (fig. 3). These rises at higher latitudes over Canada depressed the major cyclonic vortex to southern Canada, and concomitantly the westerlies shifted farther southward over the eastern United States and the Atlantic.

Another major development occurred over the central and western Pacific, where a new wave entered the westerlies as the Asiatic coastal trough retrograded during March (fig. 2B). As is frequently the case in such situations the new trough in the central Pacific and the new ridge in the west-central Pacific were associated with the northward extension of a trough and a ridge which existed earlier in the subtropical Pacific (fig. 2A). Inspection of figure 3 shows that the main height changes associated with this new wave were concentrated exactly in middle latitudes (+36 in the western Pacific and -39 in the east-central Pacific, both at 45° N.). As a result of this shortened wave spacing in the Pacific, the ridge in the eastern Pacific moved some 10° to 15° of longitude eastward between the two halves of March. This progression of the ridge, combined with increased westerlies through the lower latitude portion of the central Pacific trough, resulted in rapid motion of the trough from off California into the southern Plains and the Southwest. Although this trough by strict definition² did not build northeastward to join with the Canadian trough over Hudson Bay, maximum cyclonic curvature did extend northeastward across the Midwest and the Great Lakes. Meanwhile the subtropical High over the West Indies also shifted eastward.

² Trough and ridge are defined as points of lowest or highest latitude reached by the contours, or minimum or maximum height along latitude circles.

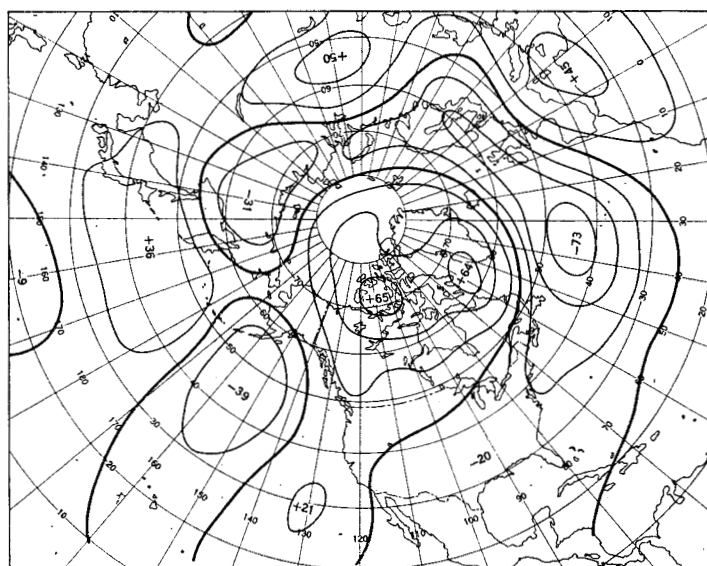


FIGURE 3.—Change in 15-day mean 700-mb. height (tens of feet) from March 1-15 (fig. 2A) to March 16-30, 1955 (fig. 2B). Largest changes occurred in Atlantic and Canada where strong blocking action developed. Note falls in central Pacific and rises in western Pacific associated with new wave development.

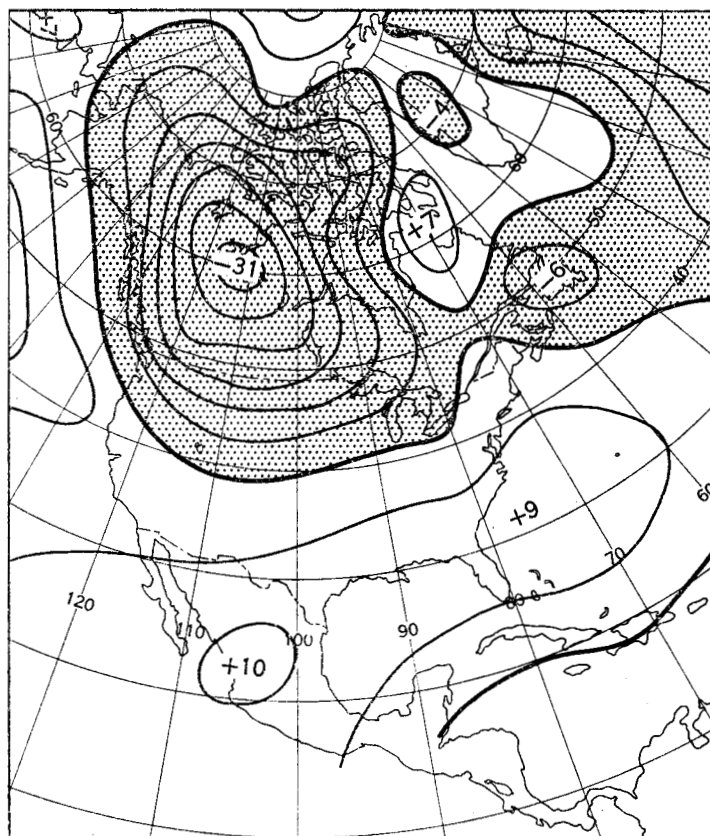


FIGURE 4.—Mean thickness anomaly (tens of feet) for the layer between 1000 and 700 mb. for March 1-30, 1955. Isopleths are drawn at 50-ft. intervals and negative values are shaded. Pool of abnormally cold air in western Canada (310 ft. or 10° C. below normal) was source for extremely cold air which invaded the United States in force late in month.

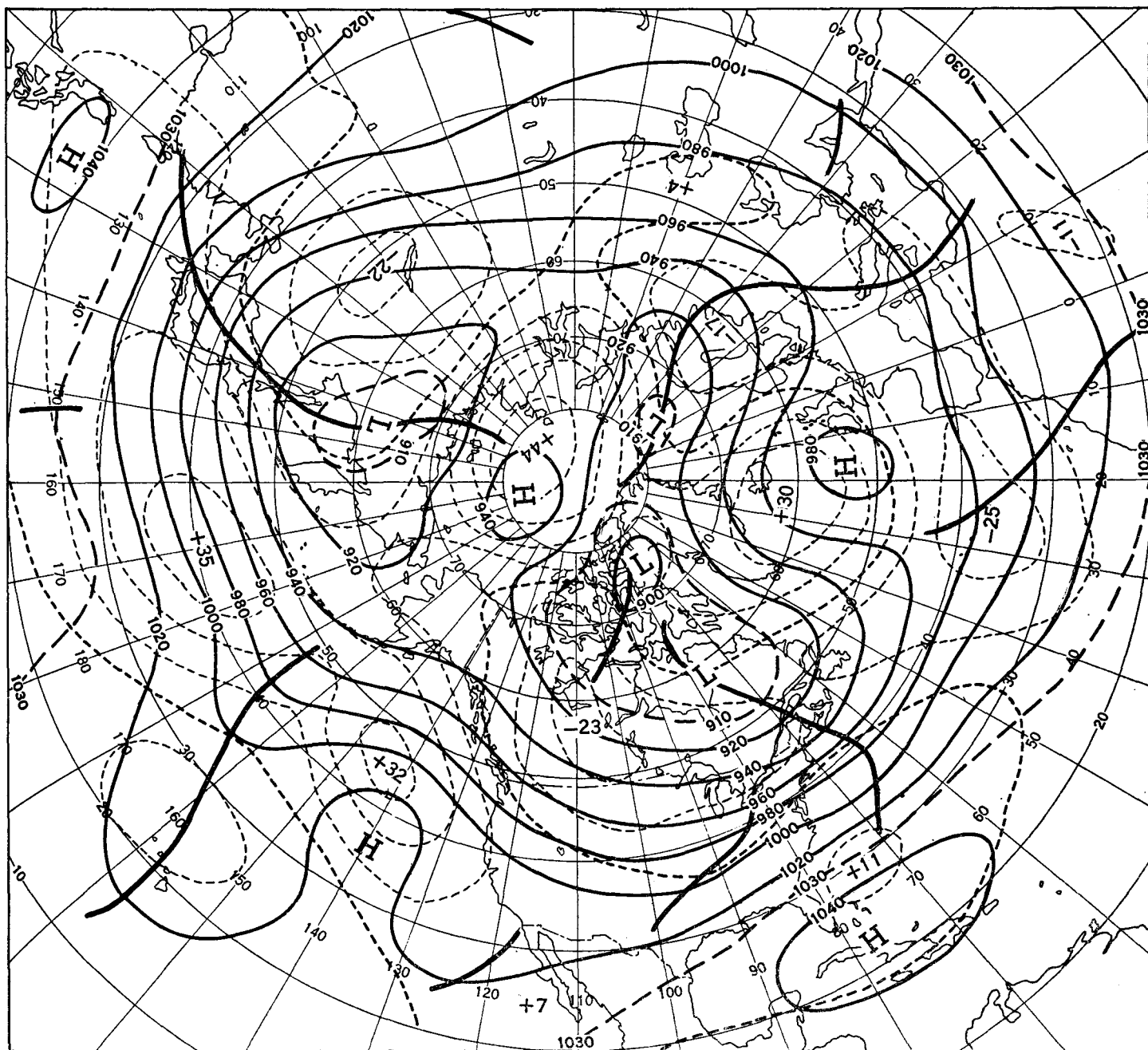


FIGURE 5.—Mean 700-mb. contours and height departures from normal (both in tens of feet) for March 1-30, 1955. Outstanding feature for North America was subpolar cyclonic vortex with associated cyclonic circulation dominating most of Canada and northern half of United States. Stronger-than-normal northwesterly flow west of Mississippi resulted in generally subnormal precipitation over country (see Chart III). Sharply tilted trough between Ohio and Texas produced band of heavy precipitation to its east.

These eastward motions of the waves at middle and lower latitudes, in conjunction with the southward shift of westerlies over the United States, operated to weaken the aforementioned confluence zone over the United States and shift the remnants of it into the Southeast (fig. 2B). The concomitant decrease of zonal flow and increase of northerly flow components over many portions of the United States now began steering cold air masses progressively farther southward in the United States cul-

minating in the final record-breaking outbreak in the fourth week of March (fig. 1D). The increasing frequency of polar Highs invading the United States east of the Continental Divide in the second half of March is evident in Chart IX.

The question naturally arises as to why the cold wave in the latter part of March was so extreme since the observed circulation pattern at the time of the outbreak was certainly not the most abnormal ever observed. At

least a partial answer appears to lie in the persistent circulation state which existed for several weeks preceding the spectacular cold wave. It has already been pointed out that the circulation pattern with a ridge in the Gulf of Alaska (a very unusual position for this time of year) and a strong cyclonic northwesterly flow over western Canada had prevailed from about mid-February through mid-March. This flow pattern was responsible for the development of a very cold pool of air over western Canada as portrayed in figure 4 by mean thickness anomalies between 700 and 1000 mb. for March. This vast reservoir of cold air in which thicknesses averaged as much as 310 feet (about 10° C.) below normal, was readily tapped as the circulation changes late in March provided an open channel for the flow of air masses from western Canada across virtually the entire United States. Day-by-day details of the motion of this cold air, including daily thickness anomalies, are treated by Kibler and Martin [1]. It is interesting to note that in January-February 1947 [4] and October-November 1951 [5] similar cold pools were also poised over western Canada, and very cold weather then ensued over the United States. Another similarity to the case of November 1951 is the fact that this month's negative thickness center over western Canada could be traced from a position over the Arctic Ocean just north of Alaska during the preceding month. The importance of considering such large-scale thermal anomalies in long-period prediction has been pointed out by Namias [6].

3. OTHER FEATURES OF MARCH CIRCULATION AND WEATHER

Although representative of the average between two differing circulation regimes (fig. 2A, B) the mean 700-mb. chart for March as a whole still exhibited some rather well-marked anomalies (fig. 5). The largest height anomaly in the Northern Hemisphere, $+44$, was observed near the North Pole in connection with a closed anticyclone. Related to this anticyclonic circulation over the Pole was the displacement of the major subpolar cyclonic vortex well to the south in Canada. Thus heights averaged below normal over western and southern Canada and the northern United States. The occurrence of the maximum negative anomaly center in western Canada was also associated with the unusual ridge location in the Gulf of Alaska, which has already been treated in terms of the 15-day mean circulation patterns.

Perhaps the most interesting feature of the cyclonic vortex over Canada was the considerable longitudinal breadth of the cyclonic curvature of the flow, i. e., from western North America to the central Atlantic. Near the southern edge of this cyclonic flow a pronounced monthly mean "jet stream" was located (fig. 6A). Maximum wind speeds in this jet occurred near the Middle Atlantic Coast where values exceeded 20 m./sec. The westerlies were organized in a single belt with a relatively

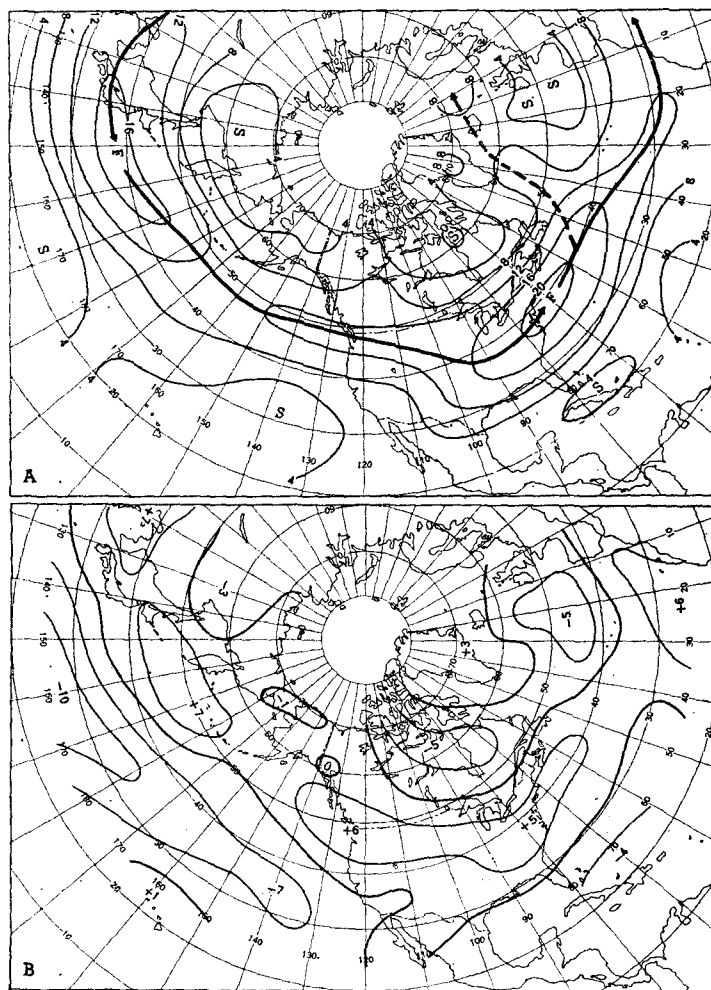


FIGURE 6.—(A) Mean 700-mb. isotachs and (B) departure from normal wind speed (both in meters per second) for March 1-30, 1955. Solid arrows indicate position of mean 700-mb. jet stream, which was stronger than normal at almost all longitudes from Korea to North Africa. Most cyclonic activity over United States (see Chart X) occurred north of jet axis in zone of strongest cyclonic shear. Dashed line delineates secondary axis of maximum wind speed which meandered around northern edge of blocking ridge in Atlantic.

well-defined central core all the way from Korea eastward to the west-central Atlantic. In the eastern Atlantic, however, there was a split in the westerlies in connection with blocking activity, but even in this zone the main branch (the southern one) was a well-organized concentrated current. Figure 6B shows that the winds along this "jet stream" were greater than normal practically all the way from Korea to North Africa. The most extensive region of subnormal wind speeds was in the Pacific at lower middle latitudes, where the maximum westerlies were shifted some 5° to 10° of latitude north of their normal location. This was related to the abnormal strength of the subtropical ridges in the Pacific during the month (fig. 5).

The cyclone tracks for March (Chart X) were concen-

trated in a relatively narrow zone near the Canadian-United States border between the Continental Divide and the Great Lakes. These storm paths closely paralleled the mean 700-mb. flow (fig. 5) and were located under the major cyclonic shear zone to the north of the jet axis (fig. 6A). East of the Lakes these cyclones either turned northeastward around the east side of the mean cyclone center near Hudson Bay or lost their identity as secondary disturbances developed along the northeast coast of the United States. These coastal disturbances were basically affected by the split in westerlies in the Atlantic, as some of the Lows were steered north-northeastward across the Gulf of St. Lawrence while others moved almost due eastward just north of the main jet axis.

Comparison of Chart X and figure 6A shows that very few cyclones occurred either directly under or south of the axis of maximum mean westerlies across the United States. Those few storms which did move across portions of the southern half of the country occurred in the second half of the month when the lower-latitude trough from the Pacific moved into the Southern Plains and the westerlies were displaced farther south (fig. 2).

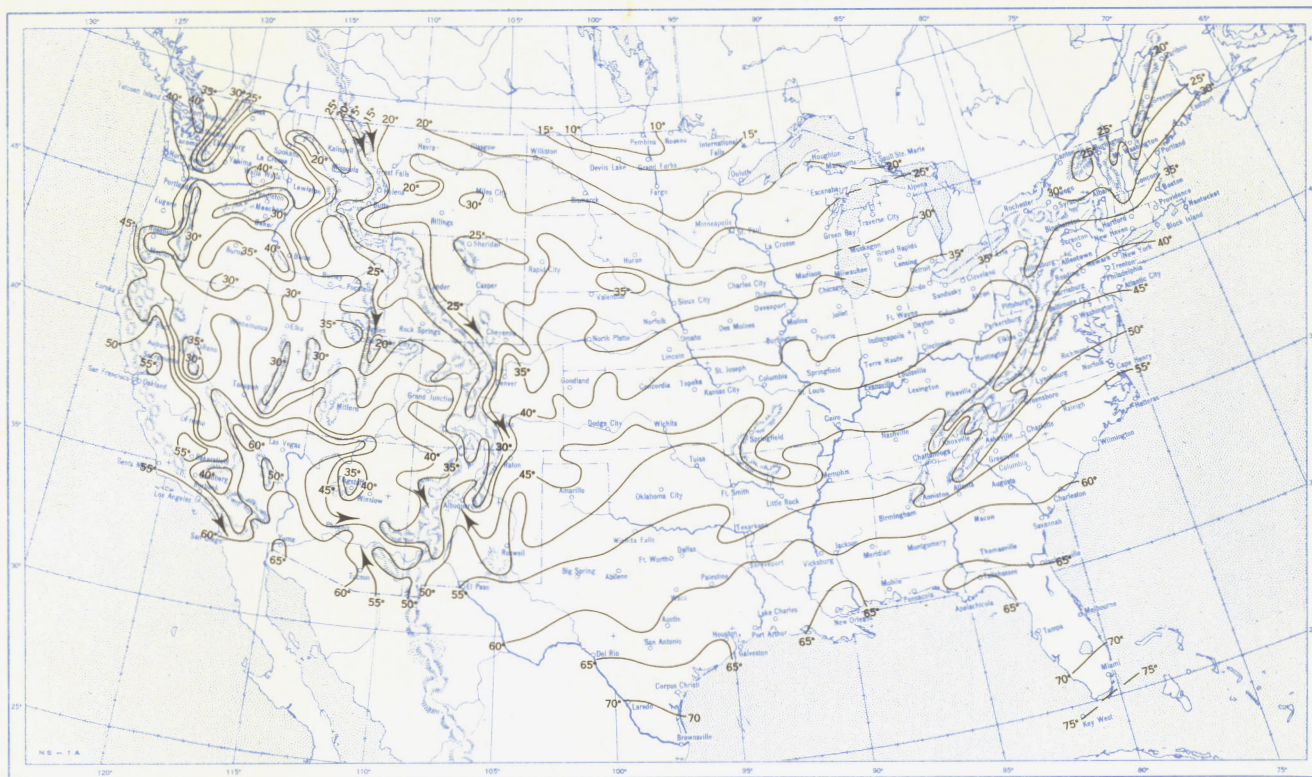
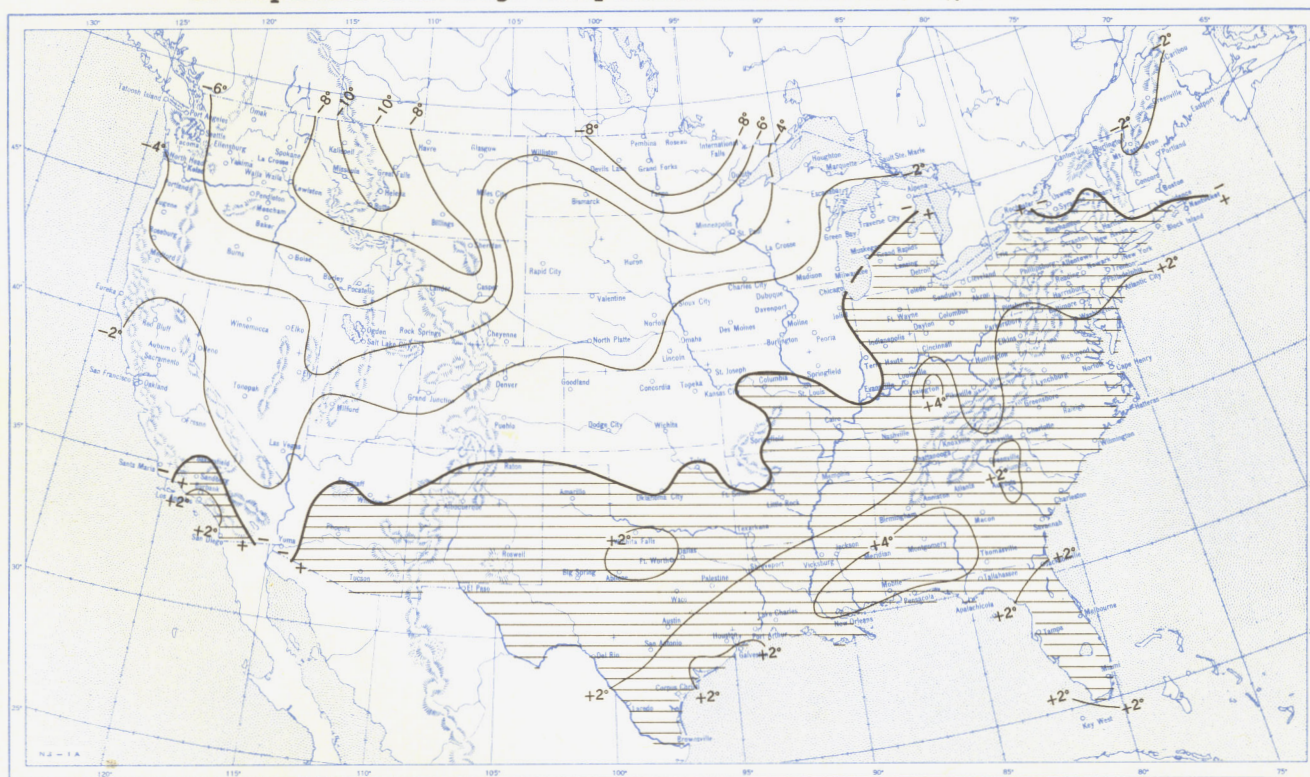
In view of the general confinement of storminess to the northern border and northeastern portions of the United States, the predominance of subnormal precipitation amounts during March (Chart III) was quite logical. The abnormal strength of west-northwesterly flow over much of the country west of the Mississippi (figs. 5, 6) provided little opportunity for significant moisture influx or for sufficiently persistent periods of upward motion to release moisture which was transported into the confines of the United States. Subnormal rainfall amounts along the Gulf Coast and Southeast were mainly related to the strength of the subtropical ridge over that area during most of the month. The prevailing subsidence associated with this anticyclonic circulation inhibited precipitation in that region, even though Gulf moisture was frequently present in the air in lower levels.

Heavier-than-normal precipitation did occur, however, in a well-defined tongue extending from Arkansas east-northeastward to the northeastern States (Chart III).

This precipitation occurred just to the east of the sharply tilted trough extending from Texas to Ohio on the monthly mean chart (fig. 5). It is quite remarkable how this trough line sharply separated this heavy precipitation from subnormal precipitation over the remainder of the Midwest. The relatively high frequency of cyclones over the Northeast (Chart X) was, of course, related to both the mean circulation and heavy precipitation in this area. Other regions of greater-than-normal precipitation over the United States were confined to the northern border region, close to the prevailing path of cyclones, and to the Pacific Northwest where the onshore flow was abnormally strong along the axis of the 700-mb. jet (fig. 6). Precipitation over all of California was subnormal, however, since it was located south of the main westerlies and flow components were mainly offshore with respect to normal (fig. 5).

REFERENCES

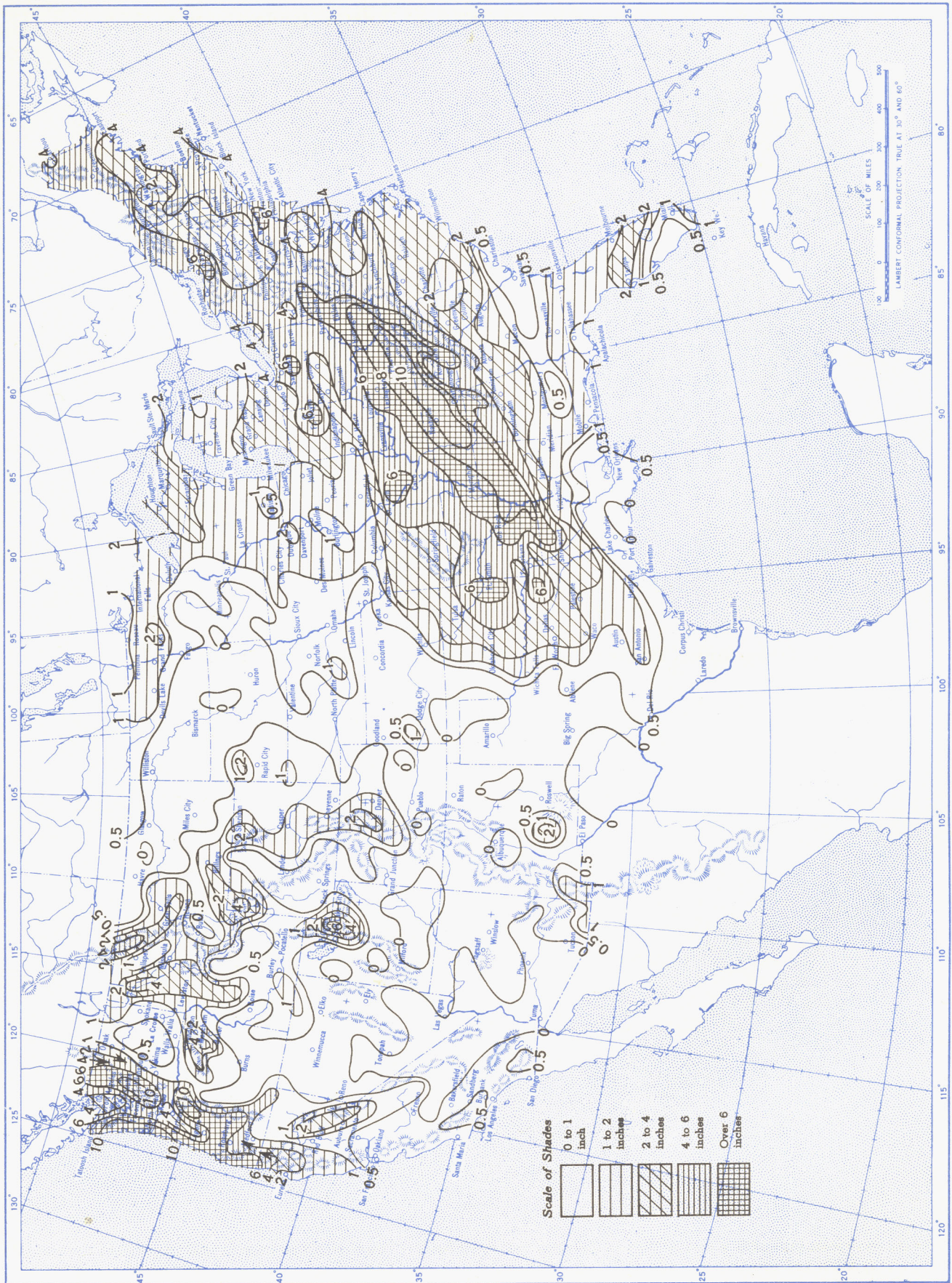
1. C. L. Kibler and R. H. Martin, "Damaging Cold Wave of March 23-31, 1955," *Monthly Weather Review*, vol. 83, No. 3, March 1955, pp. 78-82.
2. U. S. Weather Bureau, "Normal Weather Charts for the Northern Hemisphere," *Technical Paper No. 21*, Washington, D. C., October 1952, 74 pp.
3. W. H. Klein, "The Weather and Circulation of February 1955—Another February with Two Contrasting Regimes," *Monthly Weather Review*, vol. 83, No. 2, February 1955, pp. 38-44.
4. J. Namias, "Characteristics of the General Circulation over the Northern Hemisphere during the Abnormal Winter 1946-47," *Monthly Weather Review*, vol. 75, No. 8, August 1947, pp. 145-152.
5. W. H. Klein, "The Weather and Circulation of November 1951," *Monthly Weather Review*, vol. 79, No. 11, November 1951, pp. 208-211.
6. J. Namias, "Thirty-Day Forecasting: A Review of a Ten-Year Experiment," *Meteorological Monographs*, vol. 2, No. 6, American Meteorological Society, July 1953, 83 pp. (see pp. 25-26.)

Chart I. A. Average Temperature ($^{\circ}\text{F}$) at Surface, March 1955.B. Departure of Average Temperature from Normal ($^{\circ}\text{F}$), March 1955.

A. Based on reports from 800 Weather Bureau and cooperative stations. The monthly average is half the sum of the monthly average maximum and monthly average minimum, which are the average of the daily maxima and daily minima, respectively.

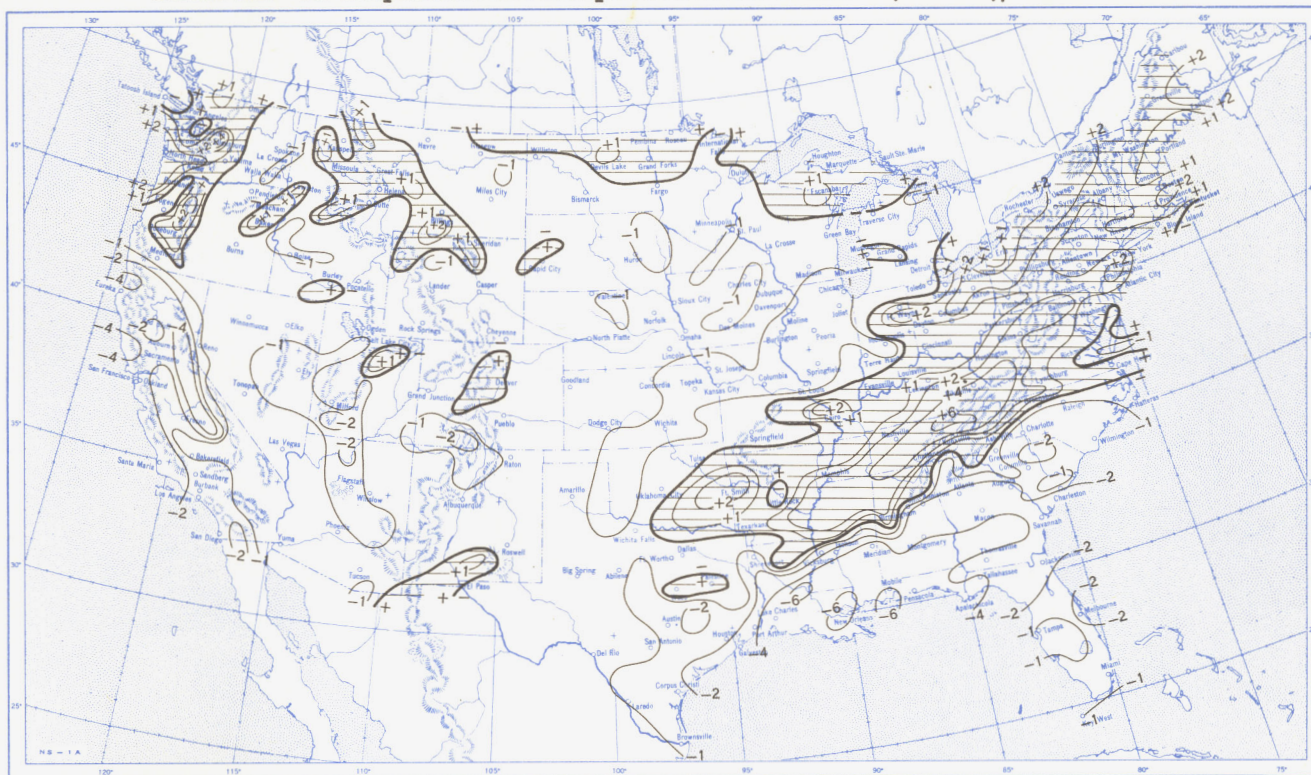
B. Normal average monthly temperatures are computed for Weather Bureau stations having at least 10 years of record.

Chart II. Total Precipitation (Inches), March 1955.

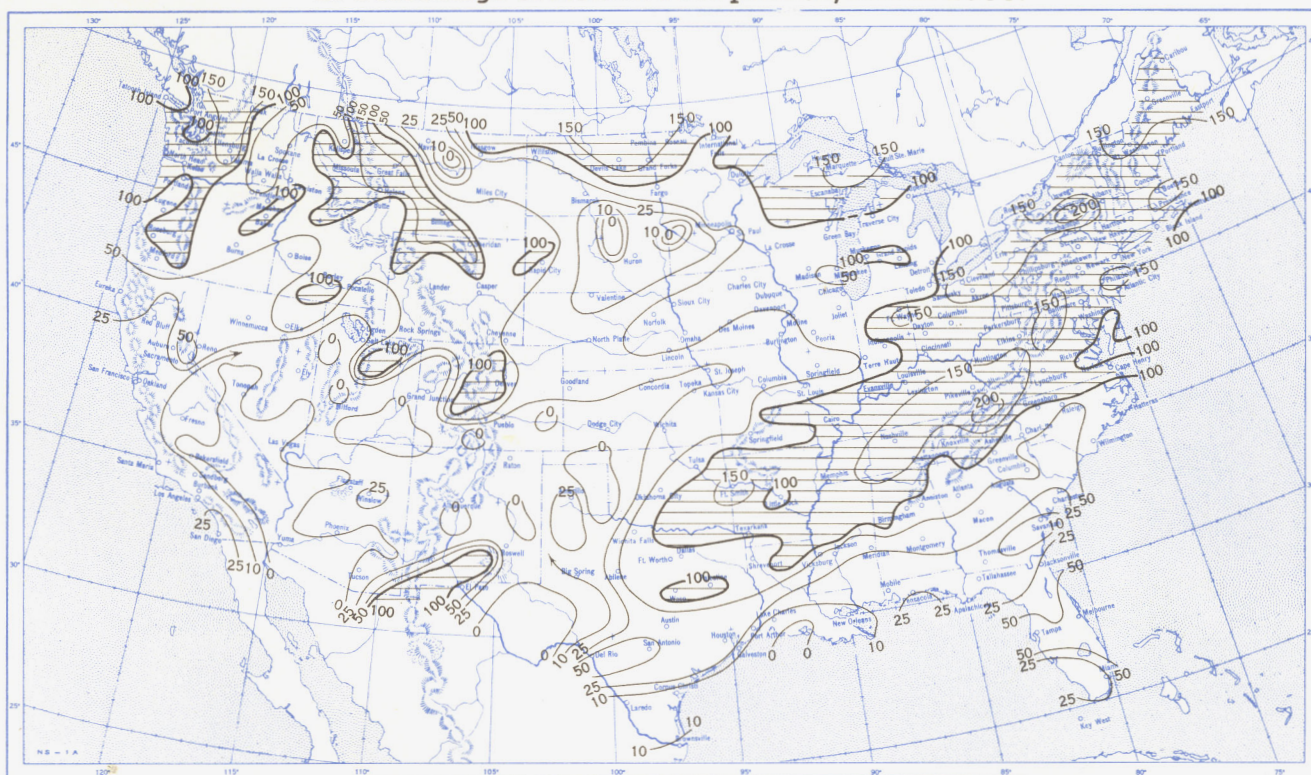


Based on daily precipitation records at 800 Weather Bureau and cooperative stations.

Chart III. A. Departure of Precipitation from Normal (Inches), March 1955.

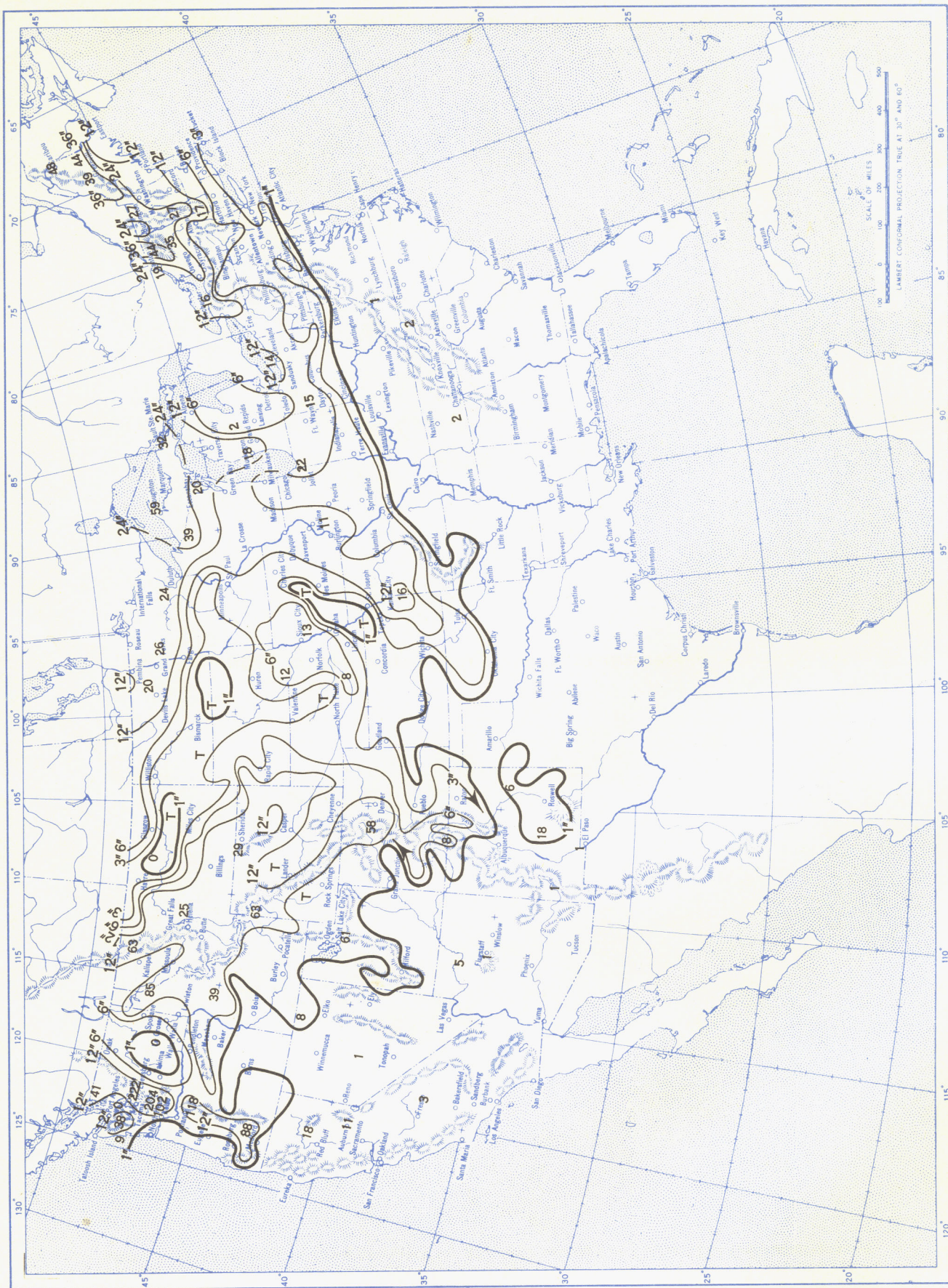


B. Percentage of Normal Precipitation, March 1955.



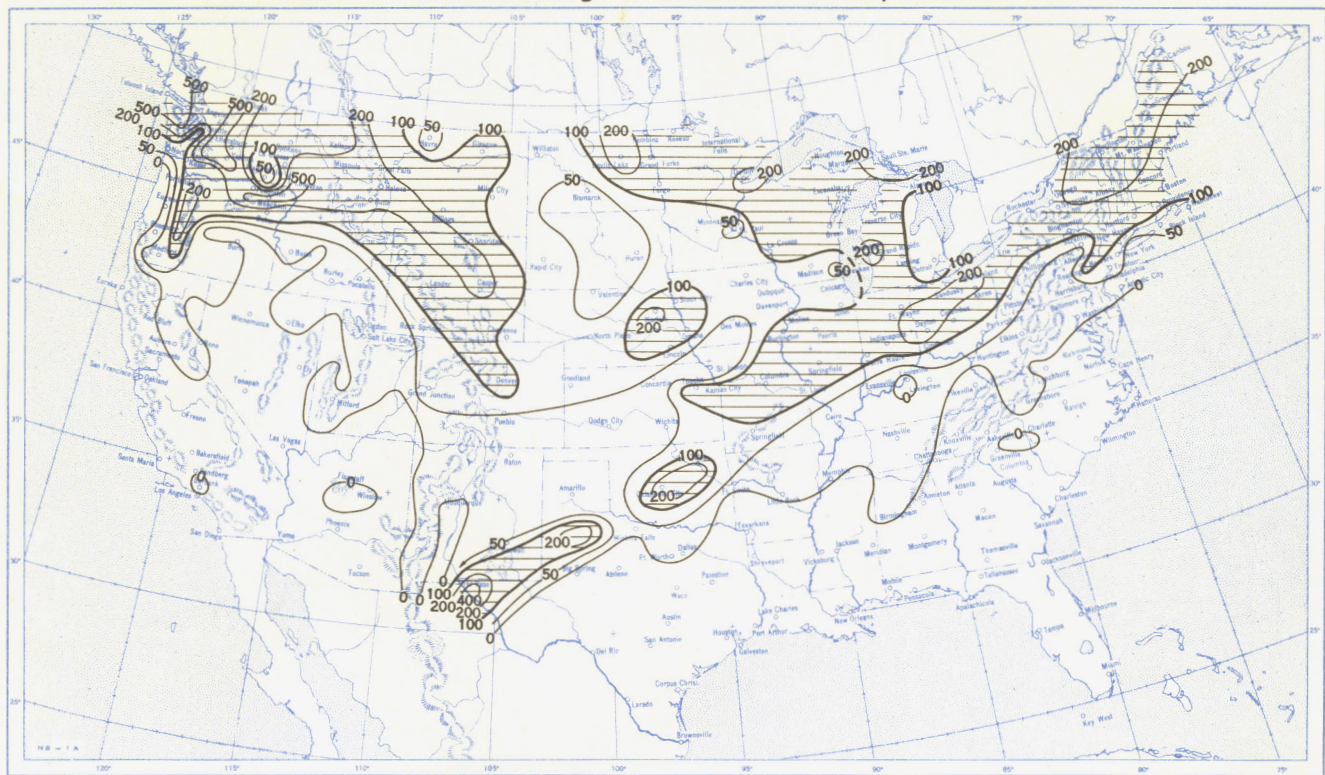
Normal monthly precipitation amounts are computed for stations having at least 10 years of record.

Chart IV. Total Snowfall (Inches), March 1955.

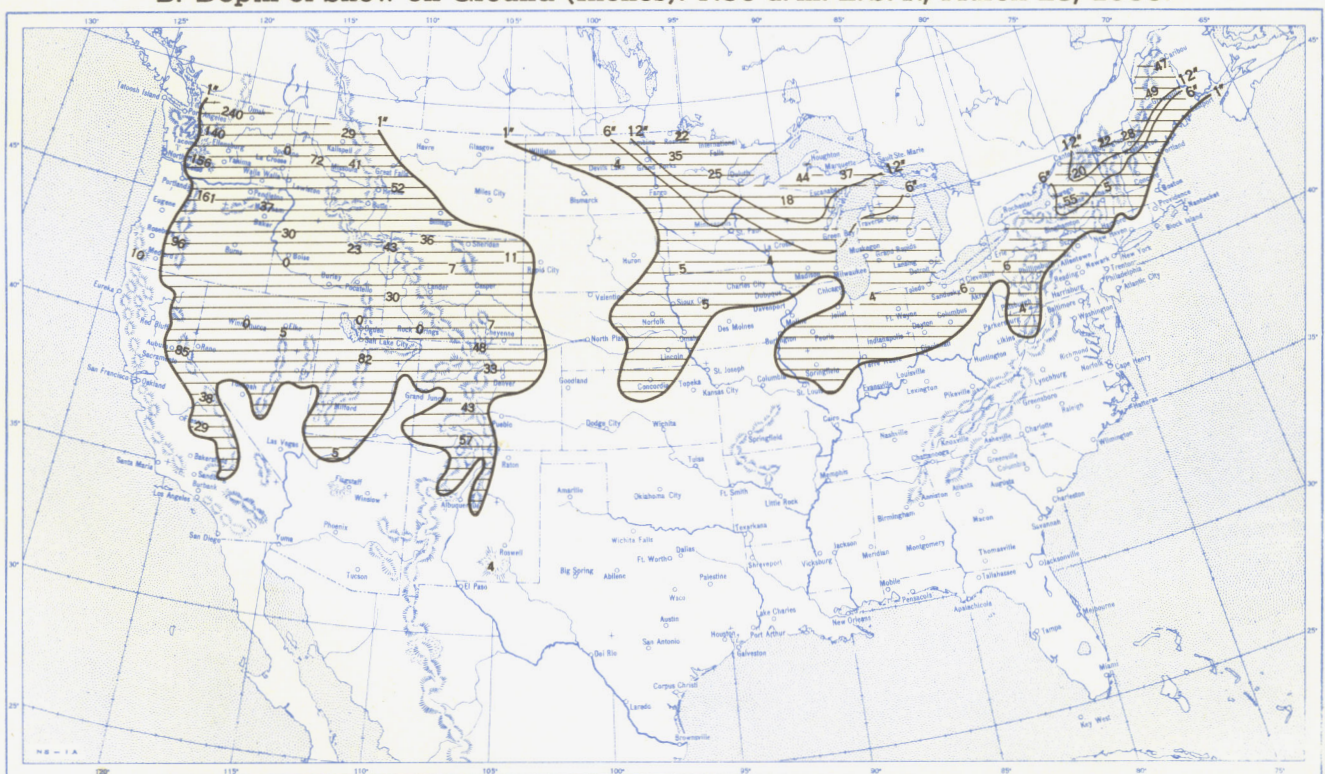


This is the total of unmelted snowfall recorded during the month at Weather Bureau and cooperative stations. This chart and Chart V are published only for the months of November through April although of course there is some snow at higher elevations, particularly in the far West, earlier and later in the year.

Chart V. A. Percentage of Normal Snowfall, March 1955.

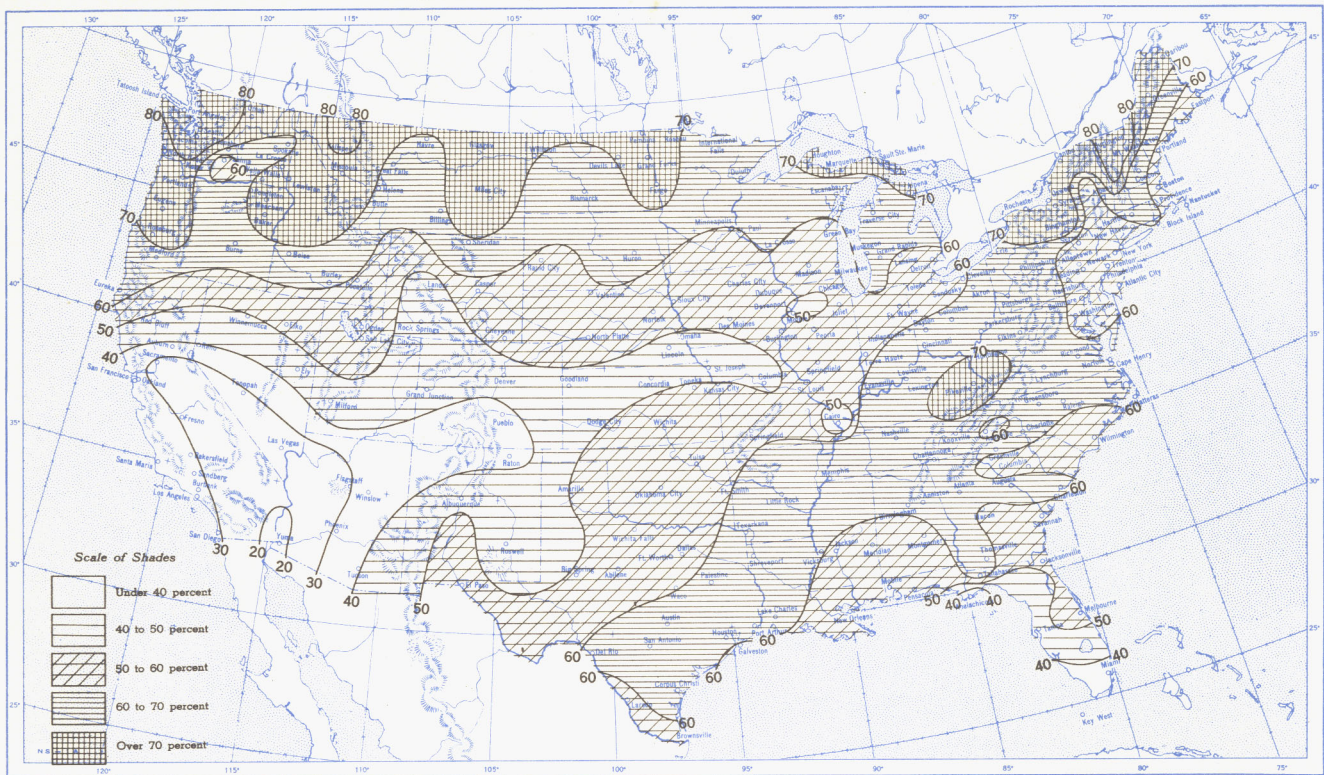


B. Depth of Snow on Ground (Inches). 7:30 a. m. E. S. T., March 28, 1955.

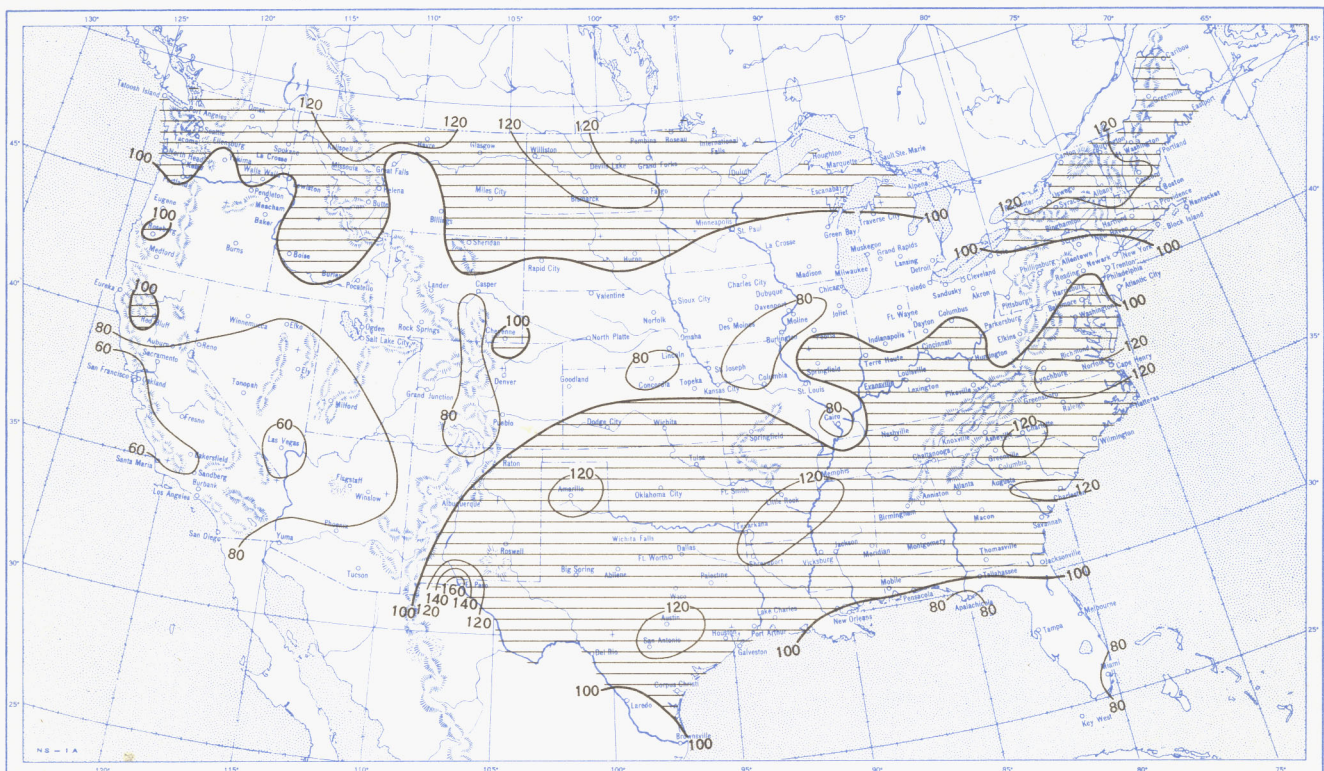


A. Amount of normal monthly snowfall is computed for Weather Bureau stations having at least 10 years of record.
 B. Shows depth currently on ground at 7:30 a. m. E. S. T., of the Tuesday nearest the end of the month. It is based on reports from Weather Bureau and cooperative stations. Dashed line shows greatest southern extent of snowcover during month.

Chart VI. A. Percentage of Sky Cover Between Sunrise and Sunset, March 1955.

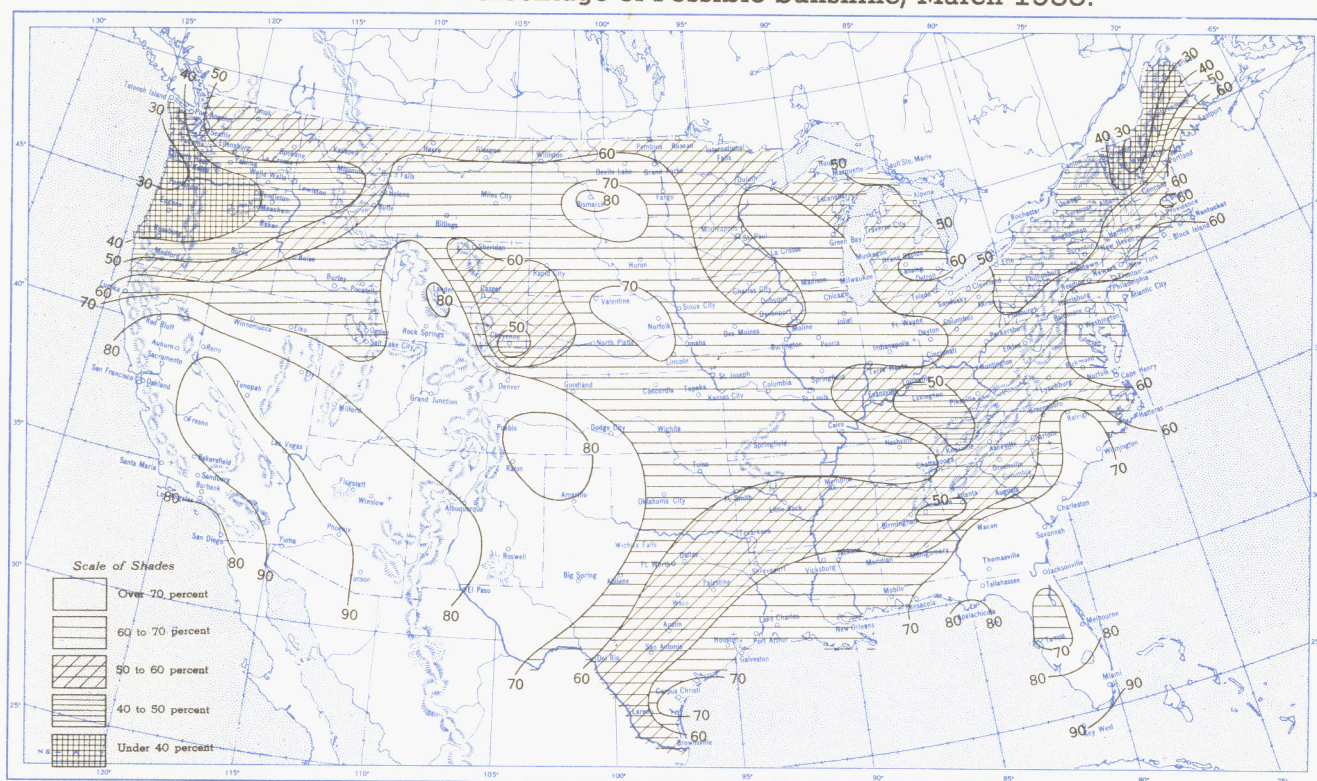


B. Percentage of Normal Sky Cover Between Sunrise and Sunset, March 1955.

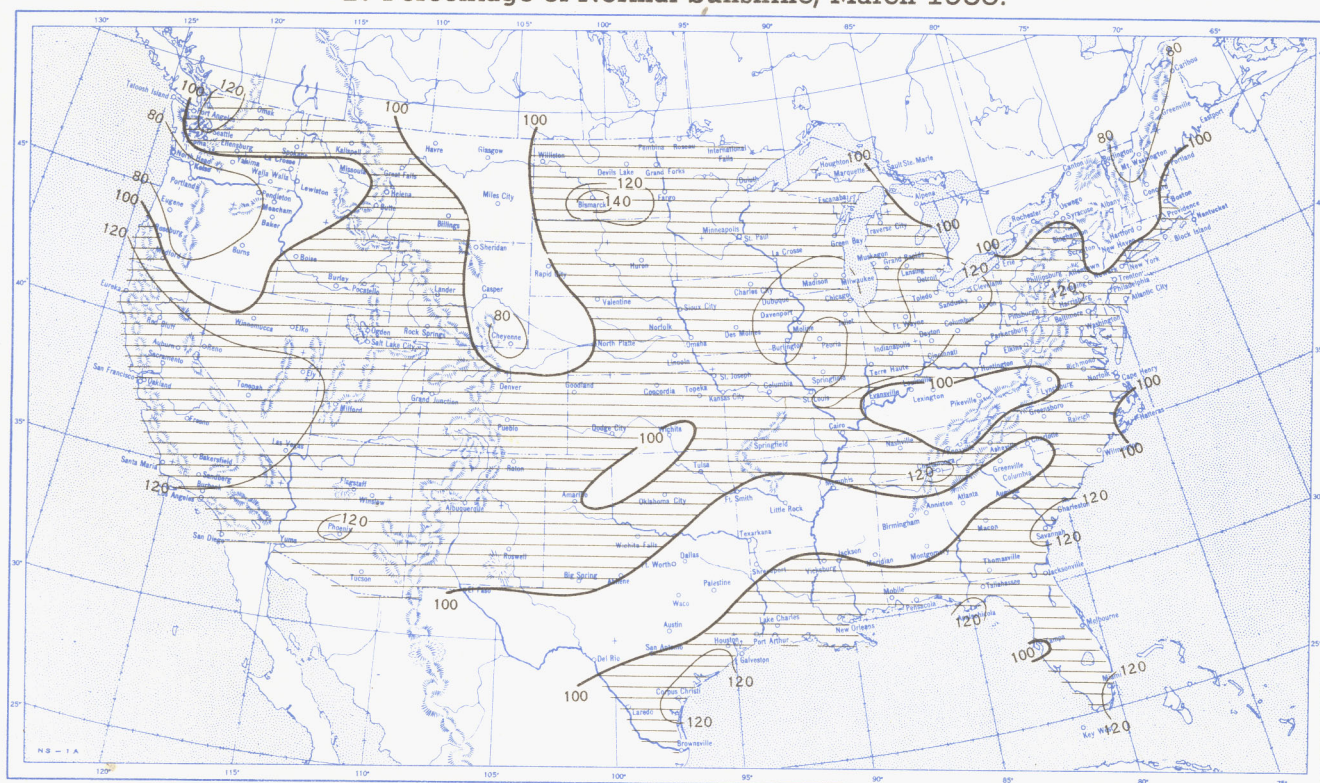


A. In addition to cloudiness, sky cover includes obscuration of the sky by fog, smoke, snow, etc. Chart based on visual observations made hourly at Weather Bureau stations and averaged over the month. B. Computations of normal amount of sky cover are made for stations having at least 10 years of record.

Chart VII. A. Percentage of Possible Sunshine, March 1955.



B. Percentage of Normal Sunshine, March 1955.



A. Computed from total number of hours of observed sunshine in relation to total number of possible hours of sunshine during month. B. Normals are computed for stations having at least 10 years of record.

Chart VIII. Average Daily Values of Solar Radiation, Direct + Diffuse, March 1955. Inset: Percentage of Normal Average Daily Solar Radiation.

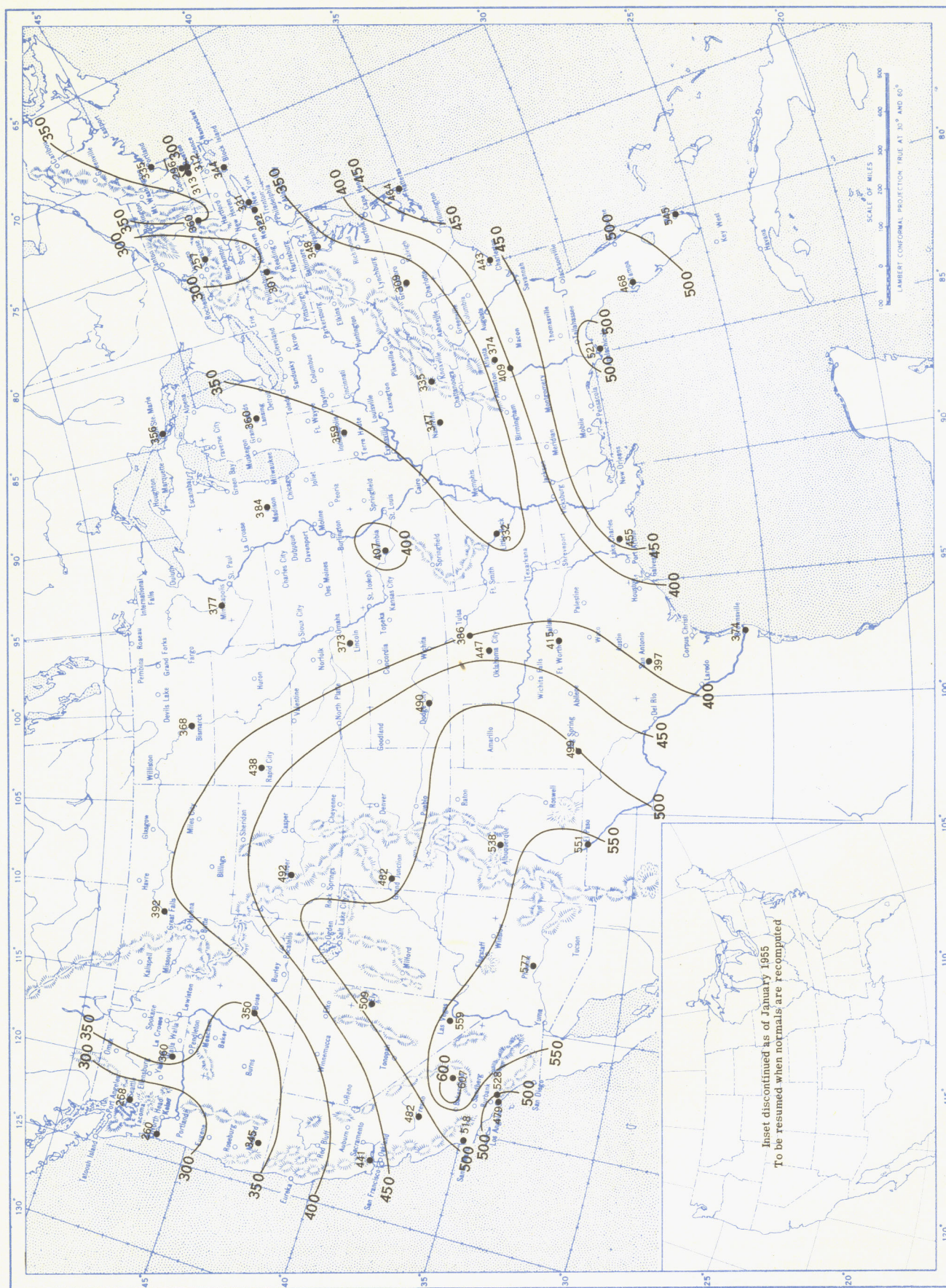
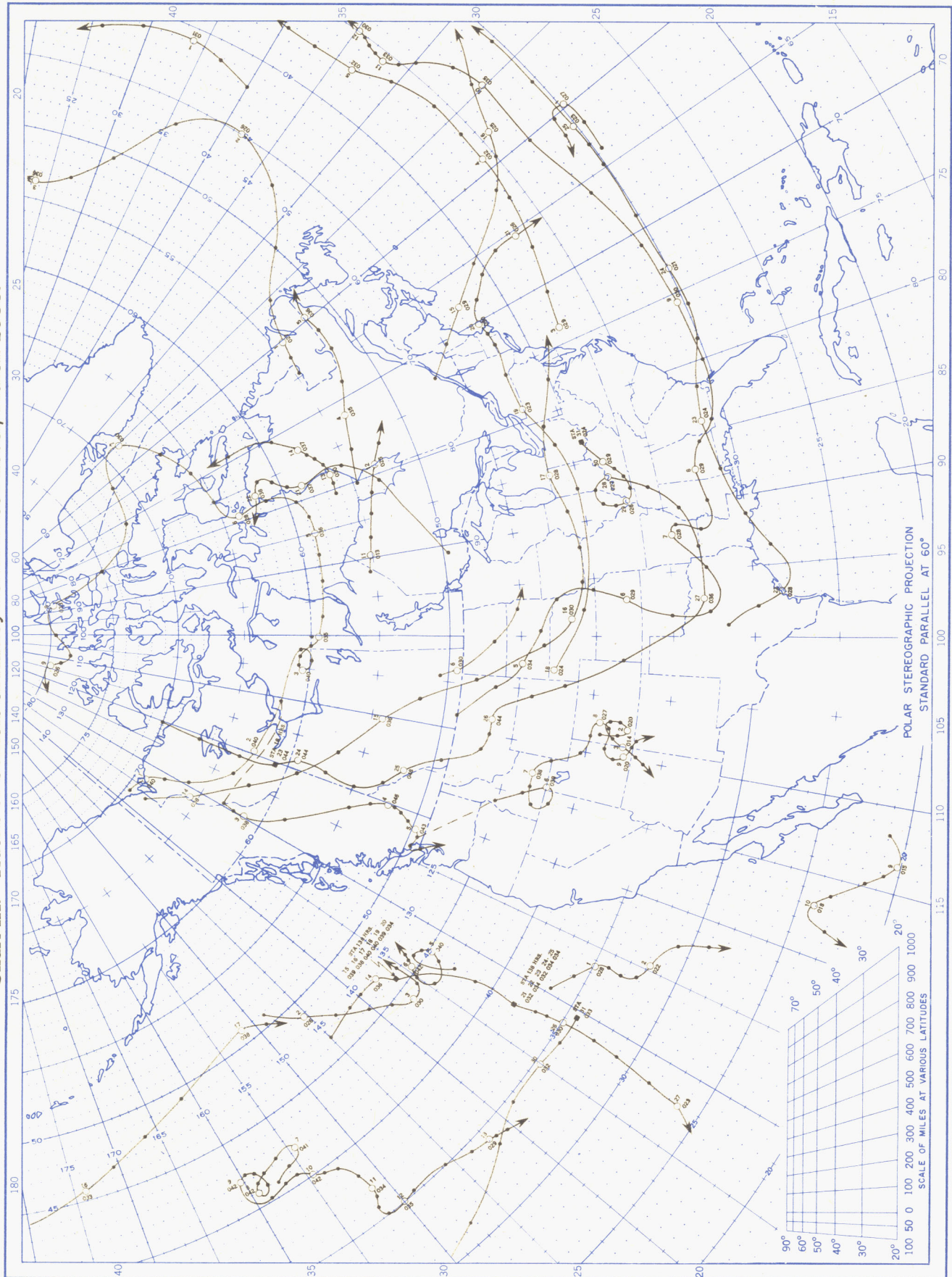


Chart shows mean daily solar radiation, direct + diffuse, received on a horizontal surface in langley's (1 langley = 1 gm. cal. cm. $-^2$). Basic data for isolines are shown on chart. Further estimates are obtained from supplementary data for which limits of accuracy are wider than for those data shown.

Chart IX. Tracks of Centers of Anticyclones at Sea Level, March 1955.



Circle indicates position of center at 7:30 a. m. E. S. T. Figure above circle indicates date, figure below, pressure to nearest millibar.
Dots indicate intervening 6-hourly positions. Squares indicate position of stationary center for period shown. Dashed line in track indicates reformation at new position. Only those centers which could be identified for 24 hours or more are included.

Chart X. Tracks of Centers of Cyclones at Sea Level, March 1955.

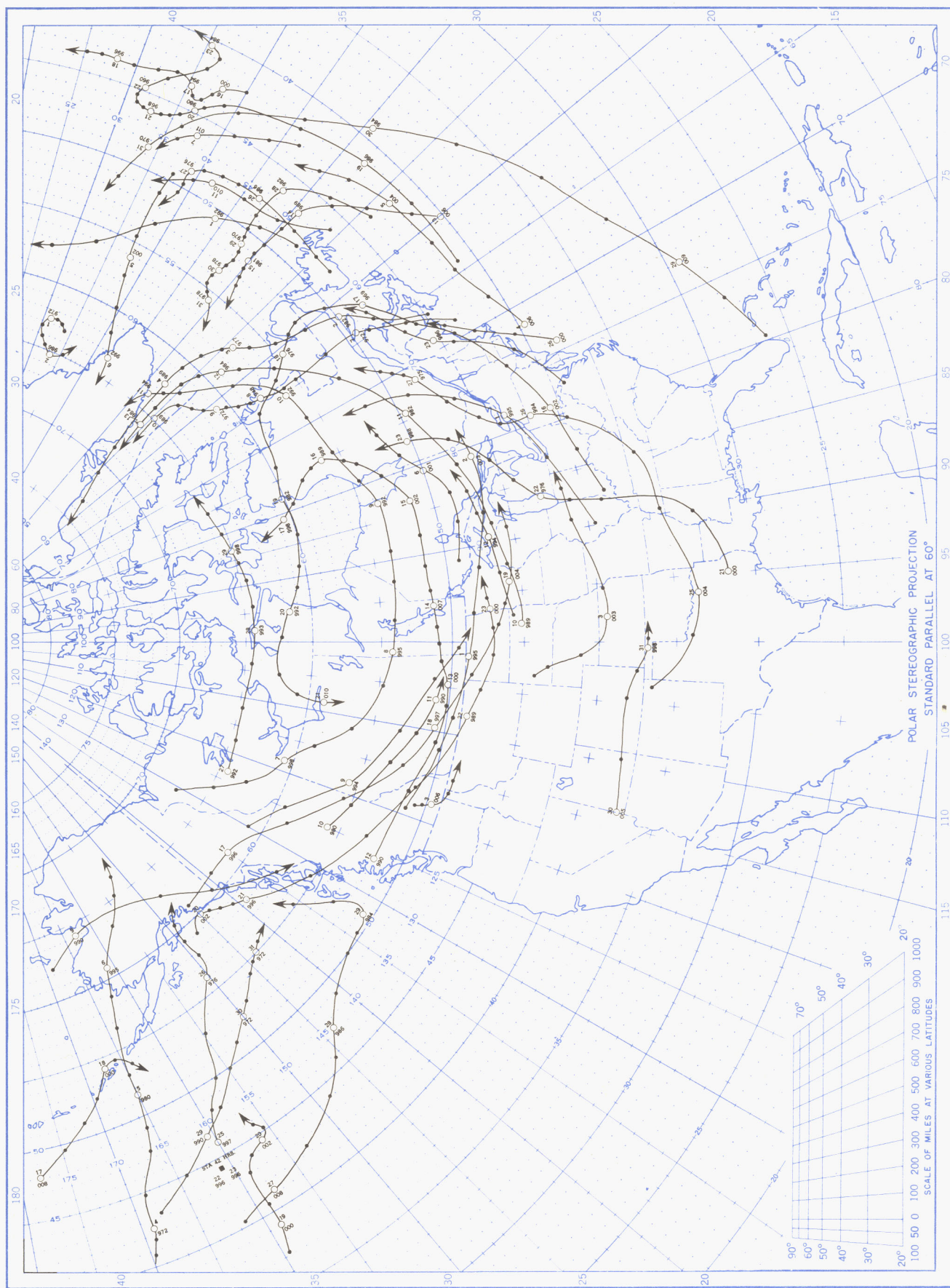
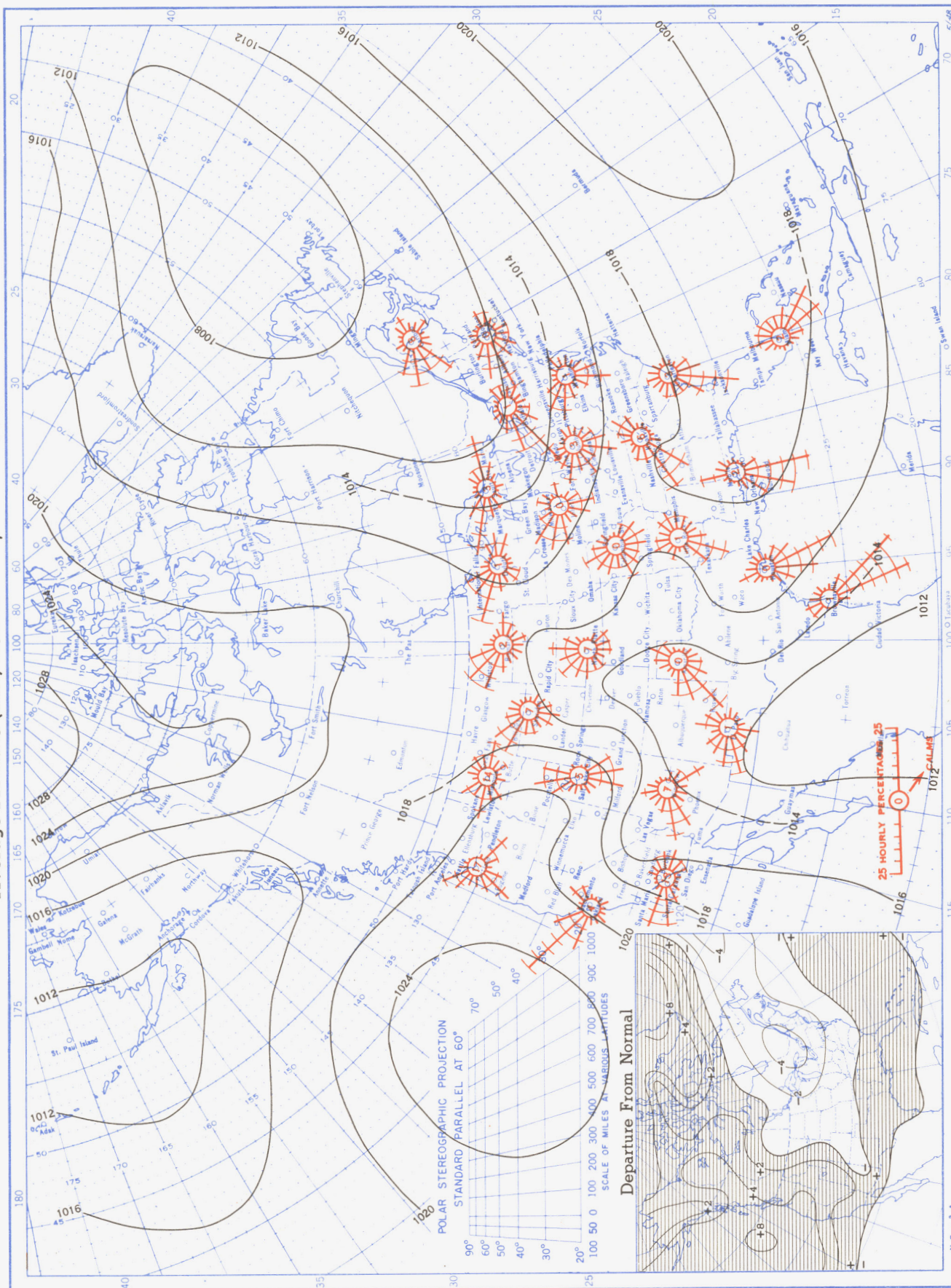
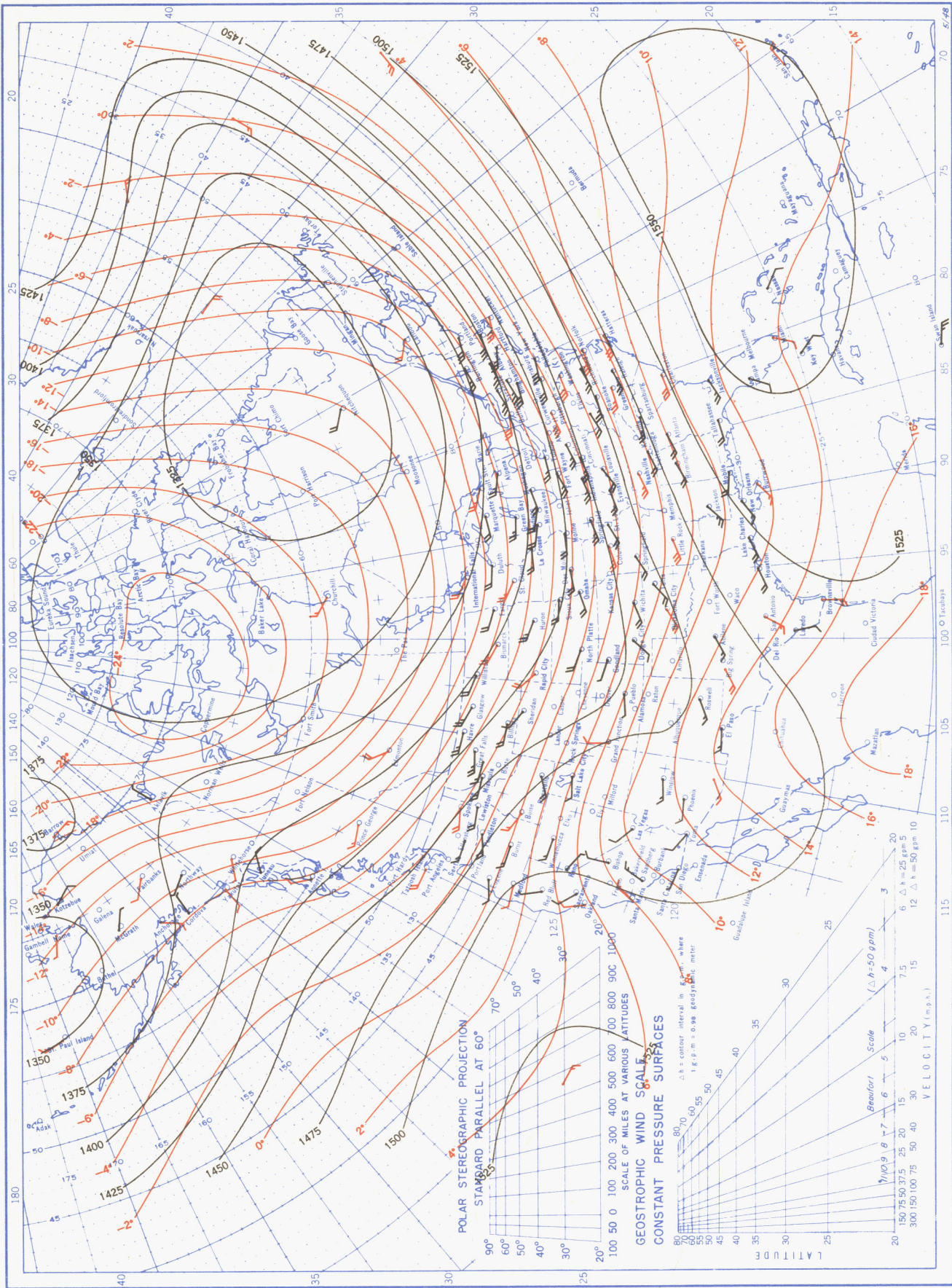


Chart XI. Average Sea Level Pressure (mb.) and Surface Windroses, March 1955. Inset: Departure of Average Pressure (mb.) from Normal, March 1955.



Average sea level pressures are obtained from the averages of the 7:30 a. m. and 7:30 p. m. E. S. T. readings. Windroses show percentage of time wind blew from 16 compass points or was calm during the month. Pressure normals are computed for stations having at least 10 years of record and for 10° inter-sections in a diamond grid based on readings from the Historical Weather Maps (1899-1939) for the 20 years of most complete data coverage prior to 1940.

Chart XII. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 850-mb. Pressure Surface, Average Temperature in °C. at 850 mb., and Resultant Winds at 1500 Meters (m.s.l.), March 1955.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T. Wind barbs indicate wind speed on the Beaufort scale.

Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins taken at 0300 G. M. T. Wind barbs indicate wind speed on the Beaufort scale.

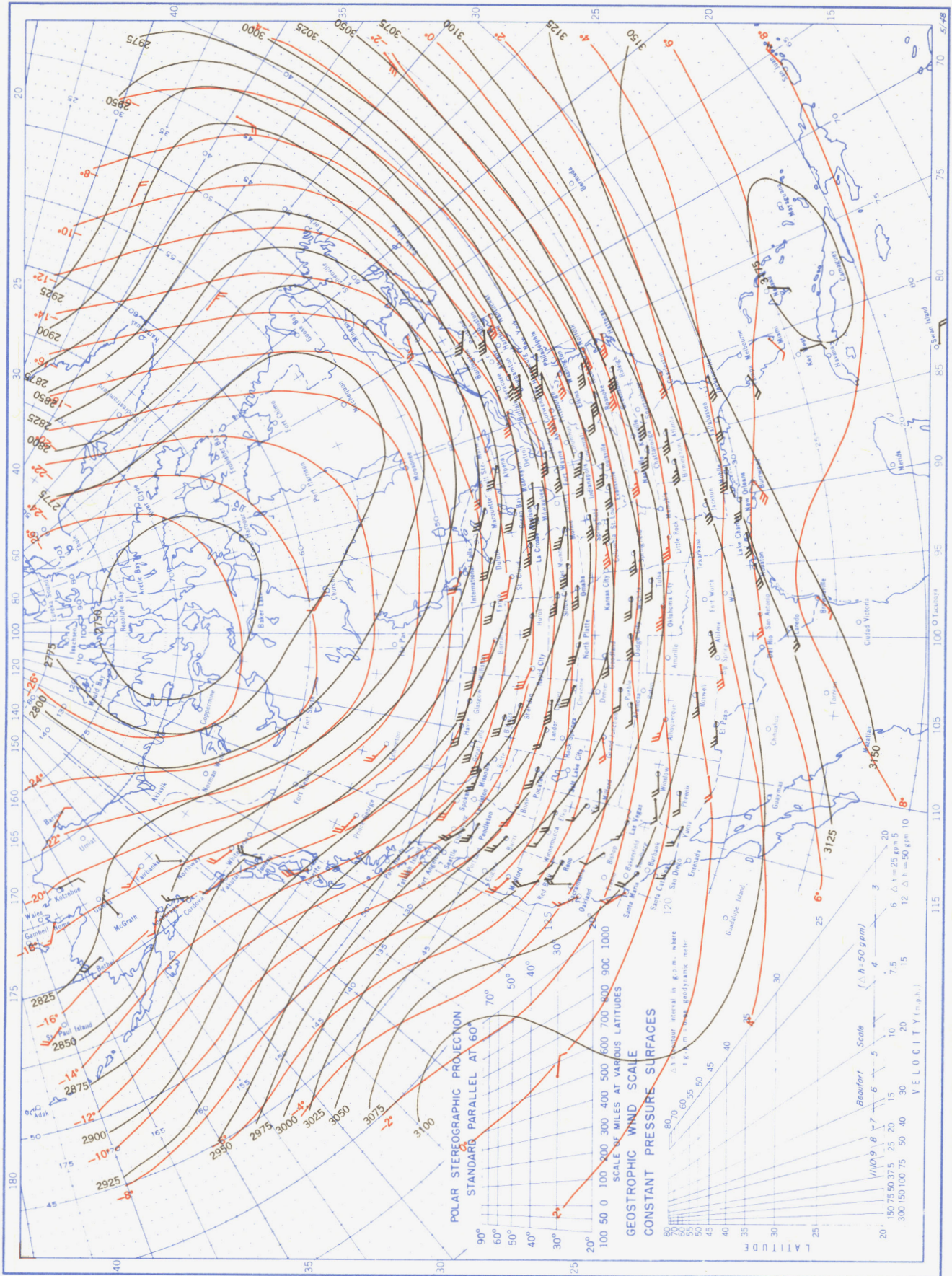
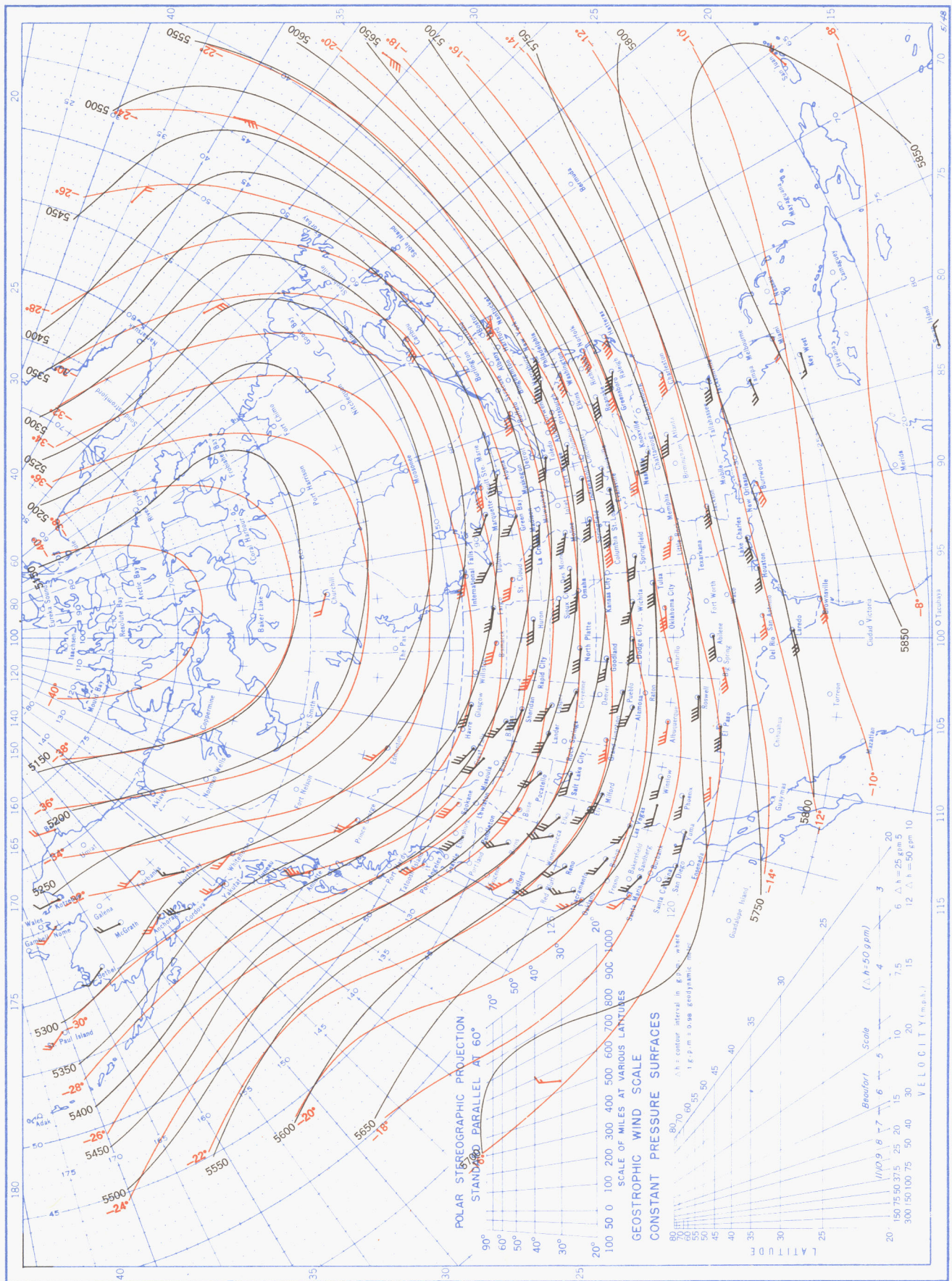
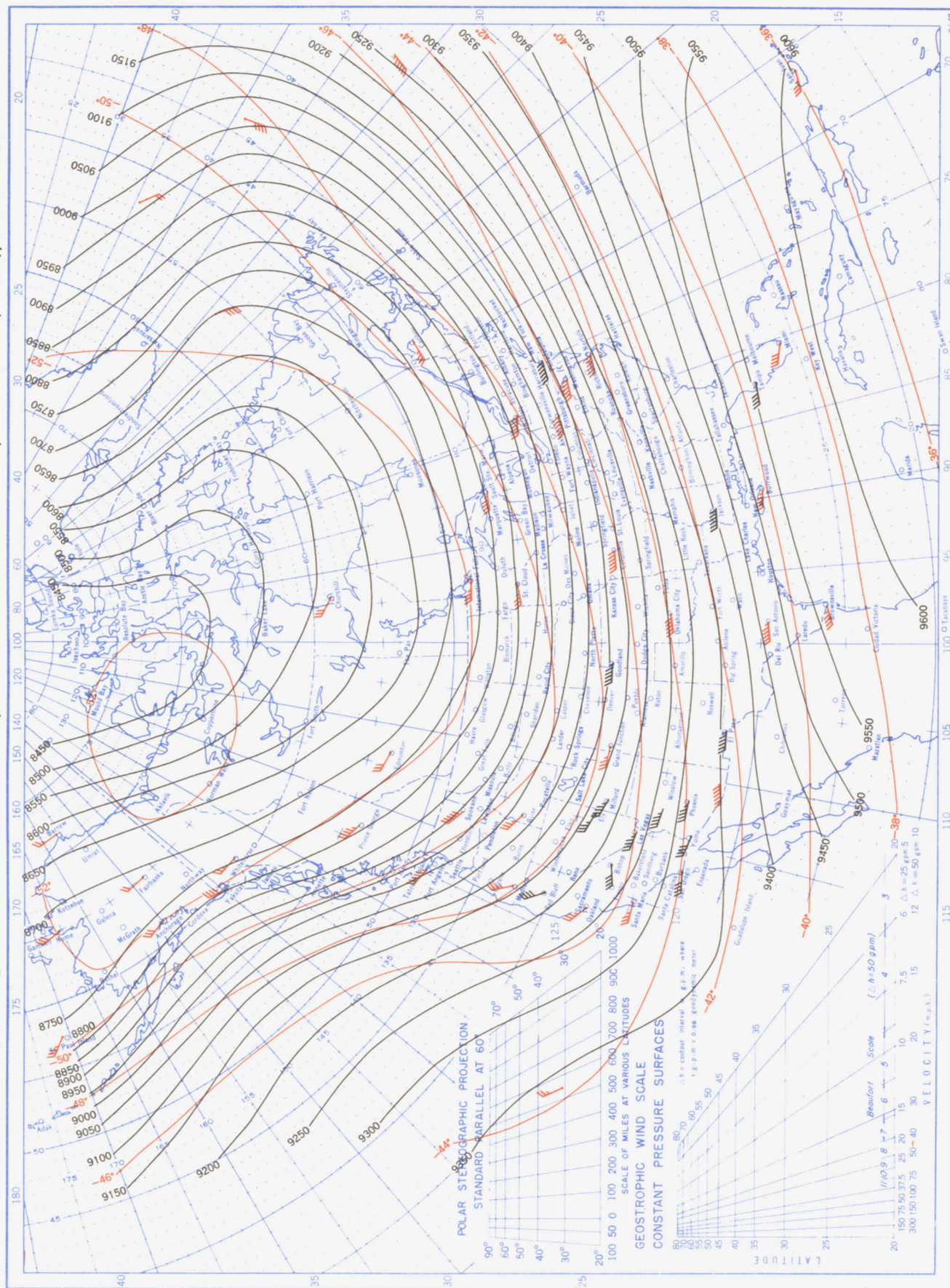


Chart XIV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 500-mb. Pressure Surface, Average Temperature in °C. at 500 mb., and Resultant Winds at 5000 Meters (m.s.l.), March 1955.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T. Wind bars indicate wind speed on the Beaufort scale.

Chart XV. Average Dynamic Height in Geopotential Meters (1 g.p.m. = 0.98 dynamic meters) of the 300-mb. Pressure Surface, Average Temperature in °C. at 300 mb., and Resultant Winds at 10,000 Meters (m.s.l.), March 1955.



Contour lines and isotherms based on radiosonde observations at 0300 G. M. T. Winds shown in black are based on pilot balloon observations at 2100 G. M. T.; those shown in red are based on rawins at 0300 G. M. T. Wind barbs indicate wind speed on the Beaufort scale.